Proceedings of the 45th Annual Meeting of the Human Factors and Ergonomics Society.
Santa Monica, CA: Human Factors & Ergonomics Society. 2001.

VISUAL DISPLAYS AND COGNITIVE TUNNELING: FRAMES OF REFERENCE EFFECTS ON SPATIAL JUDGMENTS AND CHANGE DETECTION

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This proposal describes a two-part study which illustrates "cognitive tunneling" as it affects information gathering and change detection in computer-generated terrain displays. We define cognitive tunneling as the effect where observers tend to focus attention on information from specific areas of a display to the exclusion of information presented outside of these highly attended areas. Previous research suggests that cognitive tunneling is induced by more immersive or egocentric visual displays and results in poorer information extraction and situation awareness as compared to an exocentric display of the same information. The experiment discussed here determined that failure of the observers to integrate information across the two views of the immersed display was the primary cause of the cognitive tunneling effect. In addition, participants' abilities to detect changes to objects in the environment were affected by the type of change as well as the salience of its presentation within the view.

INTRODUCTION

In a battle situation, military commanders create hypotheses about enemy actions, which they use to decide on courses of action (COAs). These hypotheses are based on their ability to visualize the battlefield, which in turn is based on acquisition and integration of information about the area of interest, such as troop locations, terrain hazards and passability, etc. Information of this type will increasingly be displayed graphically on computer-generated displays with realistic terrain information which may aid battlefield visualization. Better visualization, based on the most complete information, leads to better hypotheses and resultant COAs. However, commanders are affected by several cognitive decision-making biases, such as the anchoring heuristic and the confirmation bias, which can affect the way that information about the environment is gathered and interpreted (Tolcott, Marvin, & Bresnick, 1989). The information gathered tends to be incomplete and may not necessarily represent the true situation. Without the ability to discern how complete the information is, the commander's visualization may be compromised and result in poor COA decisions (Cohen, Freeman, & Thompson, 1997).

In our efforts to investigate the effects that display frame of reference may have on spatial judgments and change detection, we are in effect evaluating the role of metacognition in obtaining information from visual displays. Results from a previous study by Thomas, Wickens, & Merlo (1999), indicated that participants in an egocentric display condition were cognitively tunneling to certain pieces of information and ignoring or discounting other information, as compared to participants in an exocentric display condition. The pattern of results suggested that information within the initial forward field of view in the egocentric view was reported accurately, but information located in the periphery was missed or otherwise not reported. In addition, there was a marked difference in the quality and quantity of verbally reported changes to objects in the environment depending on display condition. However, it was not clear from this experiment exactly what caused certain information to be selectively reported.

We created the current experiment to specifically address potential causes of the cognitive tunneling effect by putting a greater focus on change detection as well as spatial judgments. By presenting participants with a variety of tasks, we are evaluating their abilities to obtain information from several distinct sources. The pattern of results for these tasks will provide evidence for a main cause of the effect.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2001**	2. REPORT TYPE	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **VISUAL DISPLAYS AND COGNITIVE TUNNELING: FRAMES OF REFERENCE EFFECTS ON SPATIAL JUDGMENTS AND CHANGE DETECTION**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Army Research Laboratory,Aberdeen Proving Ground,MD,21005**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Methods

In this experiment, we compared three display conditions consisting of different frames of reference. The first, or Tethered, display was created as an exocentric 3-D display, which showed the terrain from a vertical rotation angle of 60º (Figure 1). The viewpoint was "tethered" to the observer's position, represented as a tank icon in the environment, and rotated laterally such that the observer's position appeared to remain in the same position on the screen as the observer progressed through the terrain. There was a compass needle on the tank icon which always pointed north, and a 1km measurement bar was located to the left of the tank icon, to aid in making spatial judgments.

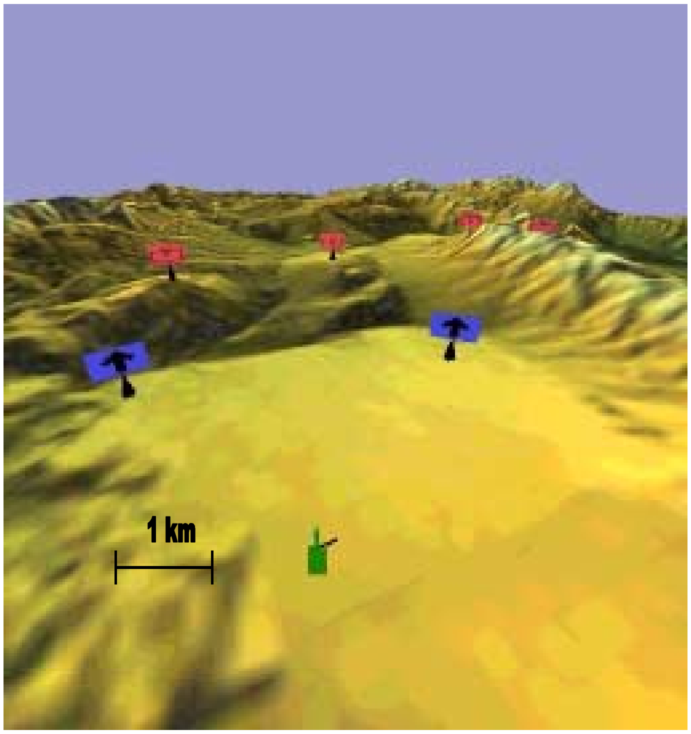

Figure 1. Exocentric ("tethered") 3D display, with observer's location represented as the tank and enemy units as signposts. The two arrows denote possible path headings for path selection questions.

The second, or Self-Pan Immersed, display was composed of two distinct views displayed simultaneously (Figure 2). The larger of the two views, which occupied most of the screen, was an immersed, egocentric view which showed the terrain from the viewpoint of the observer's position on the ground. Only 90º horizontal of the environment could be viewed at any given time, so this condition was given a panning feature which enabled the observer to control and rotate the viewpoint throughout the entire 360º range by using the mouse buttons. The smaller of the two views was a 2-D north-up contour map of the entire battle area with an overlying 10km square grid. The observer's position was depicted as a small green circle, and the current viewpoint of the 3-D view was depicted as a blue "wedge" (Aretz, 1991), which was intended to aid in maintaining visual momentum (Wood, 1984). The 10km grid and viewpoint direction wedge were intended to aid in spatial judgments.

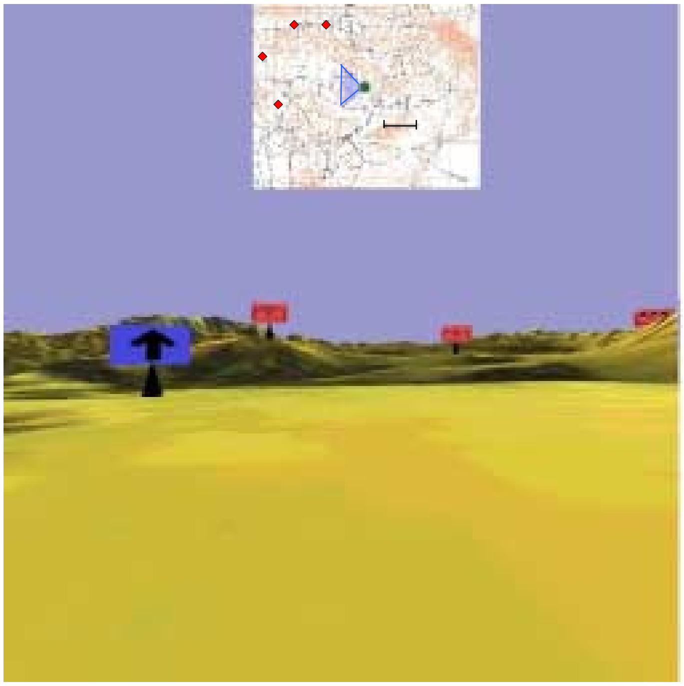

Figure 2. Immersed 3D display. Enemy units are depicted as signposts, and one arrow is visible, denoting a possible path choice for path selection questions. The small map at the top is a plan view, with the observer's location and forward view depicted by the green circle and connected blue wedge, respectively, and confirmed enemy units are depicted as small red diamonds.

The third, or Auto-Pan Immersed, display was visually identical to the Immersed display suite, but the panning feature was automated such that the viewpoint would initially pause for 5 seconds at the start of a scene, then pan in 90º segments, pausing at each 90º quadrant, until the entire 360º had been displayed. The entire panning cycle took 28 seconds to complete, and was not repeated within a scene. Participants were not able to control the viewpoint, but instead were instructed to sit passively and observe the environment as it was displayed for them. This condition was included to investigate whether a self-panning feature, as described above, would produce a high information accessibility cost as compared to an automated feature requiring no effort on the participants' part.

Information was matched across the three display conditions such that participants from any group should have been able to correctly respond to all questions.

The participants were 24 students from UIUC, and they were assigned to one of these three display conditions. They viewed their progress through the terrain in a series of 50 static slides which depicted an unfolding battle scenario. Each successive slide represented a forward movement of approximately 1.5 km from the observers' previous location, and contained much of the terrain information that was present in the previous slide, which also was intended to preserve visual momentum. Enemy objects were represented by standard military symbols and were located at various points along the observers' path.

Tasks

Participants were instructed to perform two tasks. First, they reported any detected changes to enemy objects using a screen-based menu displayed next to the terrain slide. This screen-based menu contained buttons with each symbol's unique identifying letter as well as four "change" options, so that observers could select the appropriate letter and change type for each change to an enemy object. Types of changes were: objects that appeared, objects that disappeared, objects that changed status from unconfirmed to confirmed, and objects that changed location. All changes took place between scenes, and more than one change could occur between any two scenes.

Second, participants responded to a set of computer-based questions, presented below the change menu and next to the terrain slide. These questions required the participants to make spatial and orientation judgments as well as counts of the visible enemy objects. Each scene contained either one or two questions, and once the questions were answered, the next scene was automatically displayed; therefore participants were reminded to report any changes in a scene first and then answer the questions associated with that scene.

Participants in the automated panning display group were specifically advised to allow the panning cycle to complete before responding to the questions for two reasons: first, there could be relevant information about object changes in the last quadrants of the environment that they might miss if they were attending to the question and not the scene, and second, by responding to the question before the panning cycle was completed, the cycle would be halted and that scene would automatically disappear and be replaced by the successive scene, in effect prematurely end the panning cycle before all of the environment was displayed.

Results

In change detection performance, the results indicate that type of change played a much more significant role than did the display condition (see Figure 3). There was virtually no difference in performance between the Tethered and Self-Pan Immersed display conditions, indicating that display frame of reference did not affect participants' perception of changes. However, object disappearances were clearly more difficult to detect than either appearances or status changes. Despite the identical views displayed, the Auto-Pan Immersed condition participants showed significantly worse performance on the disappearances and status changes than the Self-Panning Immersed. Based on additional evidence described below, we attribute this effect to the misuse of the automatic panning feature and not to the display frames of reference. Note: since there was only one instance of a change in location, that instance was omitted from this report but is discussed in Thomas & Wickens, 2000.

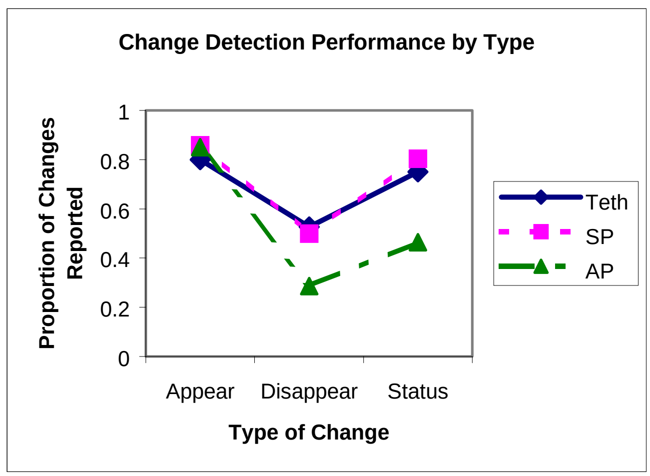

Figure 3. Performance on change detection task for each view condition by change type (omitting location changes).

Additionally, it was determined that changes located in the periphery of the Tethered view and outside the initial FFOV of the Immersed views were detected less often than centrally located (initial FFOV) changes. This finding provides some evidence that salience of the information influences cognitive tunneling, even in static exocentric views.

The computer-based questions were divided into three categories: distance judgments, direction judgments, and counts of visible enemy questions.

Distance and direction questions were used to confirm that the participants were correctly oriented within the display and knew how to use the spatial tools provided within each display type (the compass needle and 1 km bar in the Tethered condition, and the 10 km grid and wedge in the 2-D inset map of the Immersed condition). Relatively high performance in the Immersed conditions as compared to the Tethered condition suggests that the Immersed participants were frequently and accurately referring to the 2-D inset map for information about distance and direction judgments.

The visible enemy count questions were further categorized by the type and location, relative to the Immersed display, of information needed to correctly respond to the question, resulting in four categories

1. Forward questions ("Forward"), which required information presented only in the initial FFOV
2. Pan-required, unconfirmed enemy only questions ("PR-unconf"), which required Immersed condition participants to pan the entire environment (or watch passively) for information on unconfirmed enemy units, which as stated above do not appear in the 2-D inset map
3. Pan-required, all enemy questions ("PR-all"), which required the participants to pan the environment for unconfirmed enemy units while also gathering information on confirmed enemy units, from either the 3-D egocentric or 2-D inset views
4. Pan-required, inset-map questions ("PR-inset"), which required participants to pan the environment for relevant information, as well as integrate information which was ONLY located in the 2-D map

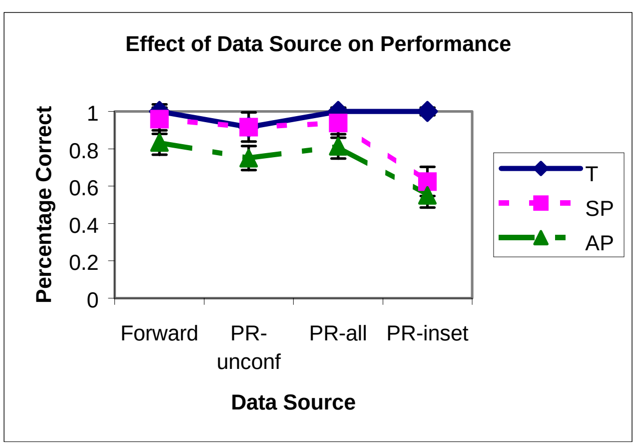

Figure 4. Performance on count of enemy visible questions for each panning category by view condition, with standard error bars.

The count of enemy visible results shown in Figure 4 suggest that cognitive tunneling was in fact an issue for both Immersed display conditions, illustrated by the drop in performance on PR-inset questions as compared to the Tethered condition's performance. The effect was limited almost entirely to those cases where information was required to be gathered from the inset map of the Immersed display *as well as* the periphery of the 3-D view. Results from distance and direction judgment questions showed that both Immersed groups were using information directly from the inset map to provide distance and direction estimations, indicating that they *were* attending to this view; however, they were not obtaining relevant enemy information. This suggests that the key cause of the effect was a failure to integrate information between the two views of the Immersed condition.

A marginal drop in performance for the Self-Pan Immersed participants, compared to Tethered participants, in the PR-all questions suggests that integration failure was not the only cause of cognitive tunneling. Panning data for the Self-Pan Immersed participants provided evidence that they actively panned to seek information, so participants did not perceive a prohibitively high information access cost for this feature. The slight drop in performance specifically on questions requiring information located solely in the periphery suggests that while Immersed participants were panning actively, they were either ignoring or discounting the peripheral information because it lacked salience as compared to information present in the initial FFOV.

A major finding of this particular study was that the automatic panning feature was a greater hindrance than help for participants in the Auto-Pan Immersed condition, as their performance on both tasks (spatial/count judgments and change detection) clearly indicates. Response time data from these participants clearly indicates that they were prematurely closing the automatic-panning feature by responding to the questions prior to viewing all of the environment and thus skipping ahead to the next scene before all of the information for the previous scene had been gathered. Evidently this feature produced its own information access costs, possibly in terms of a perceived time cost although no time limits were given to the participants. Although the overall performance in the Auto-Pan condition was always worse than the Self-Pan group, they show the same performance *trends* as the Self-Pan Immersed participants, suggesting that the display FOR had the same effects on both Immersed groups with respect to the cognitive tunneling effect.

CONCLUSION

The evidence suggests that failure to integrate accurately across two different frames of reference was a primary cause of the cognitive tunneling effect observed in the two Immersed display conditions. The change detection results also provide evidence that salience does play a minor role in producing the cognitive tunneling effect. These results indicate that immersion alone is not necessarily a key factor in inducing cognitive tunneling (although immersive views do draw attention away from non-immersive views), but that the use of dual views, especially with different frames of reference, creates a problem with accurate and complete information gathering.

ACKNOWLEDGEMENTS

Research funding for this project was provided by U.S. Army Research Laboratory under the Federated Laboratory Program Cooperative Agreement #DAAL 01-96-2-0003. The authors would like to thank Michael Barnes for serving as scientific and technical monitor, Cpt James Merlo who provided subject matter expertise, and Ron Carbonari for his programming expertise.

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